Newsletter
Mathematics & Statistics

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

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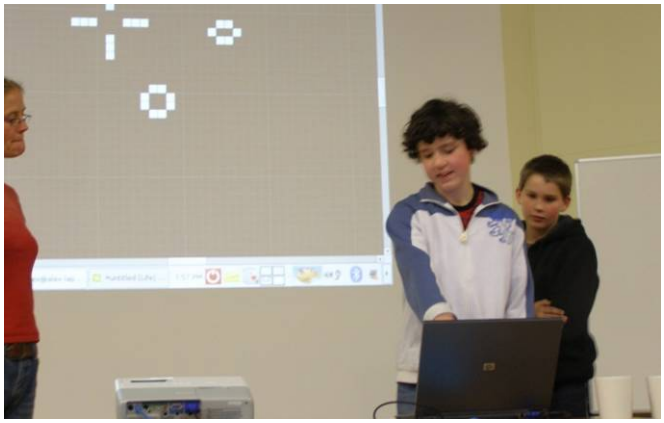
THIS ISSUE



MATHEMATICAL MISCHIEF!

On a chilly Friday night in the heart of Timaru, nearly 100 students and their teachers crowded into the Craighead Girls High School auditorium, having travelled in from all areas of South Canterbury to attend a Mathematics Enrichment evening run by the UC Mathematics & Statistics Department and the Aoraki Mathematical Association. On offer were 2 workshops: *What not to wear – an unorthodox introduction to mathematical topology* by **Clemency Montelle** and *Lizards, birds, possums and maths – what happens when a mathematician gets interested in biology?* by **Alex James**. As the evening unfolded, groups of students manipulated themselves into various topologically equivalent spaces and twisted and stretched various items of oversized clothing on and off, inside out, and back to front, marvelled at Klein bottles and real projective planes, experimented with simple ecological modelling using chocolate "M & M" populations, described birds flocking, puzzled over Sierpinksi triangles, and grappled with the famous Königsberg bridge problem. Learning, laughter and fun was had by students, teachers and presenters alike.

- Clemency Montelle

HoD NEWS

Welcome to the new semester!

A special welcome to Ronald Begg, Hannes Diener and Peter Humphries, our newly finished or finishing PhD students who are currently working on lecturing contracts to help fill the gap left by the departure of Arno Berger. Arno has taken up a position at the University of Alberta, Edmonton, in Canada and we all wish him well in his new position.

We start the new semester with 631 EMTH171 students, compared to 554 in 2007. Interestingly, MATH109-S2 has seen a reduction of 27 students from last year, while MATH108-S2 has increased by 29 students. STAT112-S2 is about the same as last year.

David Robinson will be moving to Wellington in November this year, so I wish to take this opportunity to thank him for his major contribution to our teaching programme over the last 8 years since his official retirement. We all wish him well for his new life in the Capital.

In conclusion, I would remind you all that a Cambridge/Canterbury academic exchange programme is now in existence, so you may wish to plan for that possibility.

- David Wall

WINTER WONDERLAND – *Rua Murray's children, Alison & Jasper, frolic in the June snow in the Ilam Fields*



WELCOME TO OUR DEPARTMENTAL VISITORS (E = Erskine Fellow)

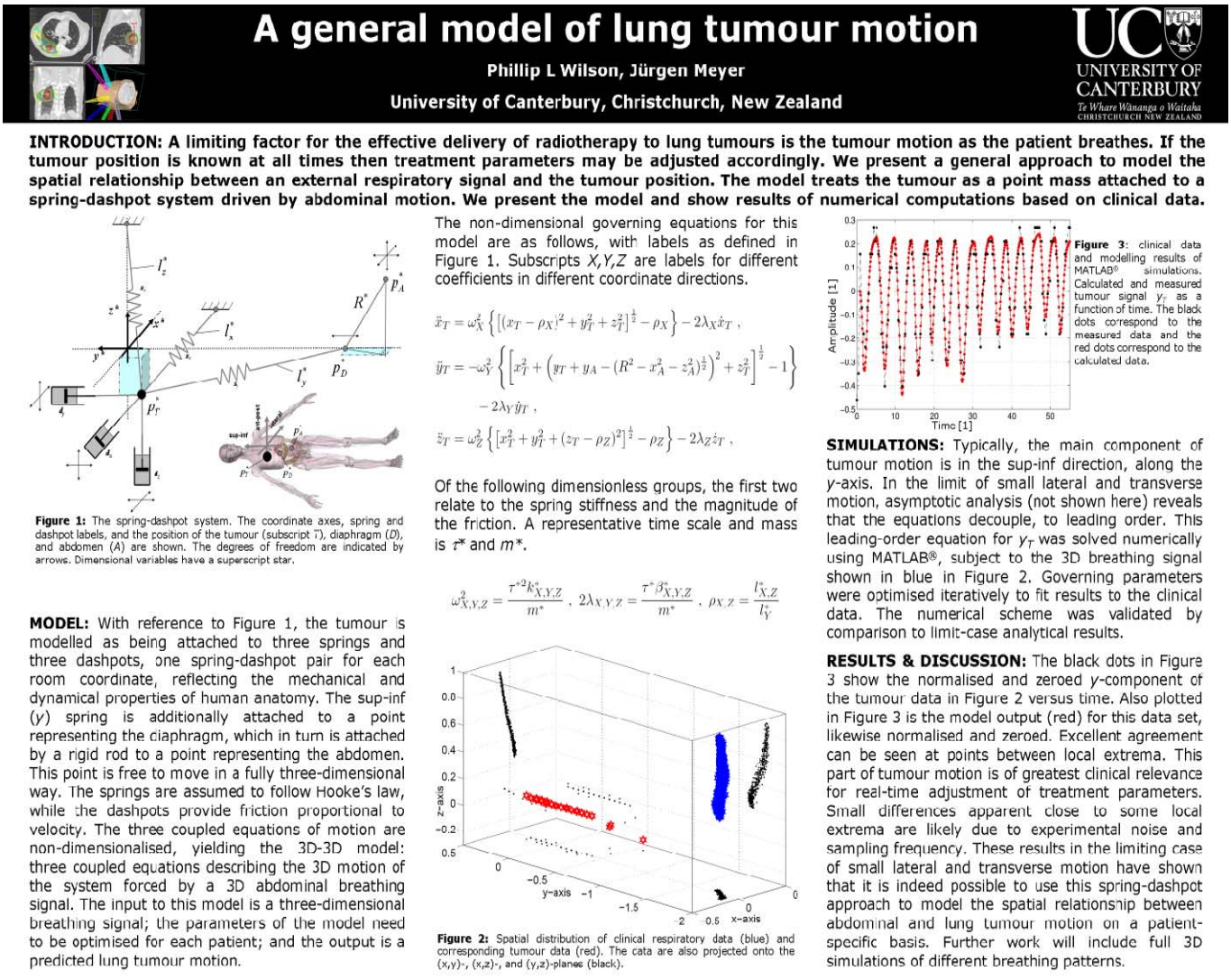
Visitor	Organization	Host	From	To	Room	Extn
David Sutton	University of York	A James	1/5/08	15/9/08	616	8876
Prof. Ron Christensen (E)	University of New Mexico, USA	C Scarrott	5/5/08	31/7/08	607	8875
Prof. Christopher Bose	University of Victoria, Canada	R Murray	1/7/08	31/12/08	605	8028
Prof. Richard Laugesen	University of Ilinois	Q Bui	8/7/08	8/8/08	607	8875
Dr Tim Burness	University of Auckland	B Martin	13/7/08	18/7/08	605	8028
Dr Christopher Voll	University of Southampton	B Martin	1/8/08	17/8/08?	607	8875
Prof Tsugunori Nogura	Ehime University, Japan	G Steinke	19/8/08	21/8/08	605	8028
Prof. Horst Malchow (E)	University of Osnabrück, Germany	A James	1/9/08	2/11/08	607	8875
Prof. Brian Sleeman (E)	University of Leeds, UK	M Plank	6/9/08	19/10/08	607	8875
Prof. Eamonn O'Brien	University of Auckland	B Martin	15/10/08	17/10/08	605	8028

Prof. Chris Bose is visiting the department from July to December 2008. Chris is on sabbatical from the Department of Mathematics & Statistics at the University of Victoria, Vancouver Island – an institution very similar to our own. His department has a faculty of around 30, while the university has a total of 15,000+ students and is set in a city of around 300,000 people. Chris works in Ergodic Theory and Dynamical Systems. He is accompanied to New Zealand by his wife Sandy and children Julia (11) and Sam (4).

- Rua Murray

CONGRATULATIONS

It was a clean sweep for New Zealand in the poster competition at the European Consortium for Mathematics in Industry 2008 held in London from 30 June to 4 July. **Phil Wilson** presented his poster entitled *A General Model of Lung Tumour Motion (*by P L Wilson and J Meyer), which won best poster in the open category alongside that of Winston Sweatman (Massey University).



A general model of lung tumour motion

Phillip L Wilson, Jürgen Meyer

University of Canterbury, Christchurch, New Zealand

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INTRODUCTION: A limiting factor for the effective delivery of radiotherapy to lung tumours is the tumour motion as the patient breathes. If the tumour position is known at all times then treatment parameters may be adjusted accordingly. We present a general approach to model the spatial relationship between an external respiratory signal and the tumour position. The model treats the tumour as a point mass attached to a spring-dashpot system driven by abdominal motion. We present the model and show results of numerical computations based on clinical data.

Figure 1: The spring-dashpot system. The coordinate axes, spring and dashpot labels, and the position of the tumour (subscript *T*), diaphragm (*D*), and abdomen (*A*) are shown. The degrees of freedom are indicated by arrows. Dimensional variables have a superscript star.

MODEL: With reference to Figure 1, the tumour is modelled as being attached to three springs and three dashpots, one spring-dashpot pair for each room coordinate, reflecting the mechanical and dynamical properties of human anatomy. The sup-inf (*y*) spring is additionally attached to a point representing the diaphragm, which in turn is attached by a rigid rod to a point representing the abdomen. This point is free to move in a fully three-dimensional way. The springs are assumed to follow Hooke's law, while the dashpots provide friction proportional to velocity. The three coupled equations of motion are non-dimensionalised, yielding the 3D-3D model: three coupled equations describing the 3D motion of the system forced by a 3D abdominal breathing signal. The input to this model is a three-dimensional breathing signal; the parameters of the model need to be optimised for each patient; and the output is a predicted lung tumour motion.

The non-dimensional governing equations for this model are as follows, with labels as defined in Figure 1. Subscripts *X,Y,Z* are labels for different coefficients in different coordinate directions.

$$\ddot{x}_T = \omega_X^2 \left\{ \left[(x_T - \rho_X)^2 + y_T^2 + z_T^2 \right]^{\frac{1}{2}} - \rho_X \right\} - 2\lambda_X \dot{x}_T \,,$$

$$\ddot{y}_T = -\omega_Y^2 \left\{ \left[x_T^2 + \left(y_T + y_A - (R^2 - x_A^2 - z_A^2)^{\frac{1}{2}} \right)^2 + z_T^2 \right]^{\frac{1}{2}} - 1 \right\} - 2\lambda_Y \dot{y}_T \,,$$

$$\ddot{z}_T = \omega_Z^2 \left\{ \left[x_T^2 + y_T^2 + (z_T - \rho_Z)^2 \right]^{\frac{1}{2}} - \rho_Z \right\} - 2\lambda_Z \dot{z}_T \,,$$

Of the following dimensionless groups, the first two relate to the spring stiffness and the magnitude of the friction. A representative time scale and mass is t^* and m^*.

$$\omega_{X,Y,Z}^2 = \frac{\tau^{*2} k_{X,Y,Z}^*}{m^*} \,, \quad 2\lambda_{X,Y,Z} = \frac{\tau^* \beta_{X,Y,Z}^*}{m^*} \,, \quad \rho_{X,Z} = \frac{l_{X,Z}^*}{l_Y^*}$$

Figure 2: Spatial distribution of clinical respiratory data (blue) and corresponding tumour data (red). The cata are also projected onto the (x,y)-, (x,z)-, and (y,z)-planes (black).

Figure 3: clinical data and modelling results of MATLAB® simulations. Calculated and measured tumour signal y_T as a function of time. The black dots correspond to the measured data and the red dots correspond to the calculated data.

SIMULATIONS: Typically, the main component of tumour motion is in the sup-inf direction, along the *y*-axis. In the limit of small lateral and transverse motion, asymptotic analysis (not shown here) reveals that the equations decouple, to leading order. This leading-order equation for y_T was solved numerically using MATLAB®, subject to the 3D breathing signal shown in blue in Figure 2. Governing parameters were optimised iteratively to fit results to the clinical data. The numerical scheme was validated by comparison to limit-case analytical results.

RESULTS & DISCUSSION: The black dots in Figure 3 show the normalised and zeroed *y*-component of the tumour data in Figure 2 versus time. Also plotted in Figure 3 is the model output (red) for this data set, likewise normalised and zeroed. Excellent agreement can be seen at points between local extrema. This part of tumour motion is of greatest clinical relevance for real-time adjustment of treatment parameters. Small differences apparent close to some local extrema are likely due to experimental noise and sampling frequency. These results in the limiting case of small lateral and transverse motion have shown that it is indeed possible to use this spring-dashpot approach to model the spatial relationship between abdominal and lung tumour motion on a patient-specific basis. Further work will include full 3D simulations of different breathing patterns.

Congratulations also to **Jennifer Brown, Miriam Hodge** and **Meghan Williams** for their successful bid to the College for 2009 CAPEX research. Miriam and Meghan are both working on Geographic Information System (GIS) related projects for their PhDs and the $15,000 grant will be used for a GIS-dedicated computer.

OLD FRIENDS

Many of you will remember Marian and Mihaela Baroni, Mathematics PhD students from Romania who graduated from the University of Canterbury in 2004 before returning to their homeland.

Courtesy of Douglas Bridges comes this photo of their daughter Andrea's recent graduation in Bucharest.

ALLAN WILSON CENTRE NEWS

1 July 2008 marks the beginning of the second 6-year round of CoRE funding for the Allan Wilson Centre for Molecular Ecology and Evolution.

Thanks to an increase in annual funding, AWC2 will now have 12 PIs, comprising the PIs and AIs from AWC1, including Mike Steel, and two new PIs - Professor Paul Rainey (Massey, Albany) and Dr Richard Newcomb (Hort Research)) together with 9 new AIs, including Associate Professor Charles Semple, and our former PhD student Associate Professor David Bryant (now at University of Auckland Maths).

AWC2 plans to offer 20 summer studentships each year - 5 studentships targeted to Maori, and a total of twelve 3-year postdocs over the coming 6 years, as well as a number of PhD scholarships. In AWC2, the three research themes are: Genomics and Bioinformatics; Biodiversity; and Origins of the Peoples and Biota of the Pacific and New Zealand.

The current directors, Professors Mike Hendy and David Penny, will continue for some months until a new director and deputy director are appointed from the current PIs. A number of meetings are being organised in early 2009 to coincide with the 200th birthday of Charles Darwin on 12 February - in particular, BioEd (see http://awcmee.massey.ac.nz/IUBS_BioEd_2009/) and our annual phylogenetics meeting, in Kaikoura (see http://www.math.canterbury.ac.nz/bio/events/kaikoura09/).

– Mike Steel

JAPANESE SCENES

Kanazawa Castle and the Kenrokuen Gardens in Kanazawa, taken by Douglas Bridges during a recent trip to Japan.

CONFERENCES & VISITS

Rick Beatson: to visit Dr Wolfgang zu Castell at the Helmholtz Institute Munich in August, to work on zonal basis function methods for tomography, in the course of an EPSRC-funded visit to the UK to work with Prof. Jeremy Levesley (Leicester) and Dr Oleg Davydov (Strathclyde).

Jennifer Brown: to attend the NZSA Annual Conference in Hamilton, 1-2 September 2008. Talk entitled *A New Adaptive Sequential Design for Sampling Rare and Clustered Populations.*

Richard Brown: to attend the SMB Conference at the University of Toronto, 29 July – 2 August 2008. Talk entitled *A meta-population model for the growth of nasella tussock.*

Qui Bui: research visit to Macquarie University to collaborate with Professor Xuan Dong, 24 August – 13 September 2008-07-17.

Hannes Diener: to attend the Summer School & Conference on Mathematics, Algorithms and Proofs, International Centre for Theoretical Physics in Trieste, Italy, 11-29 August 2008.

Daniel Lond: to attend a course on Algebraic Groups and Related Topics at the University of Birmingham, 15-19 September 2008.

Clemency Montelle: to attend the 2008 Australasian Association for the History, Philosophy and Social Studies of Science Conference at RMIT University Melbourne, 7-10 July 2008. Title of talk: *History of Mathematics*.

Phil Wilson: awarded a COE Operational Research Grant to visit Prof. Huaxiong Huang at York University, Canada, for approximately 2 weeks at the end of September 2008.

PAPER PRESENTED

PL Wilson, S Takagai, H Huang: *The lipid layer at the mesoscale: a physical continuum model* (European Consortium for Mathematics in Industry (ECMI 2008), 30 June – 4 July 2008, London.

PAPERS SUBMITTED:

Steel M, Szekely L & Mossel E: *Phylogenetic information complexity: Is testing a tree easier than finding it?* (Journal of Theoretical Biology).

Steel M & Faller B: *Markovian log-supermodularity and its applications in phylogenetics* (Applied Mathematics Letters).

PAPERS PUBLISHED

R E Begg, D J N Wall & G C Wake: *The steady-states of a multi-compartment, agesize distribution model of cell-growth* (Euro. Jnl of Applied Mathematics 00 (2008)

J Berger & D S Bridges: *The anti-Specker property, a Heine-Borel property, and uniform continuity* (Archives for Math. Logic 46 (7-8), 583-592, 2008

D S Bridges (Published Book Chapter): *A reverse look at Brouwer's fan theorem* (One Hundred Years of Intuitionism, 1907-2007, eds van Atten M, Boldini P, Bordeau M, Heinzmann G), Publications of the Henri Poincaré Archives, Birkhäuser, Basel 2008.

Michael H Chappell, Jennifer A Brown, John C Dalrumple-Alford, Aziz M Ulug and Richard Watts: *Multivariate analysis of DTI data improves the detection of microstructural damage in young professional boxers* (Magnetic Resonance Imaging – online, 2008)

Bandelt, Hans-Jürgen & Fischer, Mareike: *Perfectly Misleading Distances from Ternary Characters* (Systematic Biology 57:4, 54—543, 2008)

Iris Loeb: *Indecomposability of* R *and* R\{0} *in Constructive Reverse Mathematics* (Logic Journal of IGPL 16, 269-273, 2008)

Iris Loeb: *Factoring out Intuitionistic Theorems: Continuity Principles and the Uniform Continuity Theorem* (Logic and Theory of Algorithms, Lecture Notes in Computer Science Vol 5028/2008, pp 379-388, A Beckmann, C Dimitracopoulos, B Löwe, eds.)

Bhalchandra Thatte (AWC Postdoc)**:** *Combinatorics of Pedigrees 1: Counterexamples to a reconstruction question* (SIAM J Discrete Math. 22(3), 961-970, 2008.

FULBRIGHT SCHOLARSHIPS

Fulbright New Zealand offers the following scholarships for postgraduate study and research in the USA, at any institution and in any field of study:

Fulbright Platinum Triangle Scholarship in Entrepreneurship:
for a promising NZ graduate student to complete a Master's degree at a US university in a knowledge economy-related field and to gain professional work experience in the US and NZ.

Fulbright-Ministry of Research Science & TechnologyGraduate Awards: for promising NZ graduate students to undertake postgraduate study or research at US institutions in areas targeted to support growth and innovation in NZ.

Fulbright-EQC Graduate Award in Natural Disaster Research: for a promising NZ graduate student to undertake postgraduate study or research at a US institution in the area of natural disaster research.

Fulbright New Zealand General Graduate Awards: for promising New Zealand graduate students to undertake postgraduate study or research at US institutions in any field.

Applications for 2009 Fulbright NZ Graduate Awards close 1 August 2008.